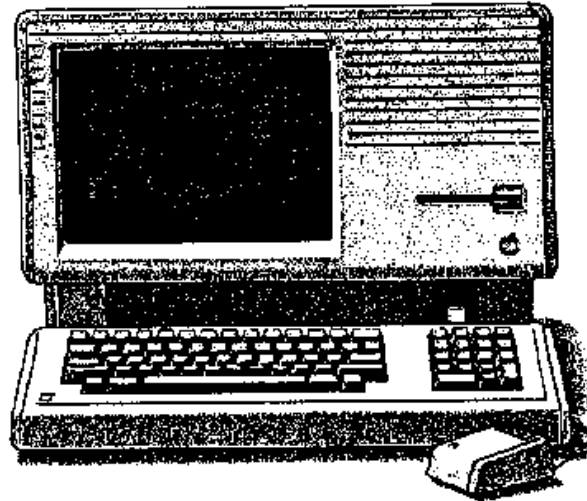




Apple Lisa Computer Historical Information



Jim Sachs on Apple Computer and the Mouse Project

<http://library.stanford.edu/mac/primary/interviews/sachs/trans.html>
23 December 2000

Interview with Jim Sachs

Jim Sachs on Apple Computer and the Mouse Project

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About Jim Sachs

Jim Sachs was one of the designers of the mouse used on the Lisa and Macintosh. The design that he, Dean Hovey, David Kelly, Rickson Sun, and James Yurchenco produced has become a classic in product design. In contrast to earlier, laboratory-produced mice, Sachs and his collaborators at the design firm of Hovey-Kelly (later IDEO) produced a mouse that had a rugged design, was extremely reliable, and easy to produce. As Sachs put it, "We moved the mouse from the lab to the living room." Virtually every mouse uses elements described in a patent Sachs and his colleagues received in 1988.

From there Sachs went on to the toy company Worlds of Wonder, where he managed the engineering of the computerized teddy bear Teddy Ruxpin. In 1995, he designed a prototype electronic book, and with Tom Pomeroy founded SoftBook Press to develop the product. Sachs is currently Chairman and CEO of SoftBook Press, which was recently acquired by Gemstar-TV Guide.

About the Interview

The interview was conducted on March 29, 2000, in Sachs' office at Softbook, in Redwood Shores. There is occasional construction noise in the background (the office park housing Softbook's offices was still under construction), and Sachs' phone. This transcript was made on 28 July 2000, and reviewed by Sachs on 1 August 2000; a final version was generated on 2 August 2000.

A copy of the unedited AIF file has been deposited in Stanford's Special Collections department.

Background and Education

Pang: Maybe we could start with you saying a little bit about your own background and training, and how you got into the business of designing mice.

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The Invisible Mouse

Sachs: Well, let me start by responding to a comment you made before the tape started, that one of the reasons you were looking into the mouse was that with all the information about the Macintosh, the mouse gets lost and is just sort of there. For those of us involved in the mouse, we actually smile at that, because our objective was to make it seamless and invisible. There's a saying that a service impeccably delivered is nearly invisible, just like a fabulous restaurant where your wine glass is always full and you don't know why. The fact that the mouse was non-obtrusive and natural is the result of a lot of work that even predated the work that we did.

First Exposure to Computers

That in a way has been the essence of my career: to make things that are easy to use, make things attractive, make things pleasant. My career has spanned twenty-something year so far. I grew up in New Hampshire, and in 1967 started programming. I was in Hanover, New Hampshire, where Dartmouth College is, and Kemeny and Kurtz were writing BASIC. Kemeny's son was in my class. An NSF grant gave free computer time to all kids in school; so I had unlimited use of a mainframe computer, and a timesharing terminal. I learned to use the computer then, and I was hooked.

There was another computer there, a PDP-9, that various Dartmouth grad students were writing programs for, doing graphical user interfaces that were joystick or pen operated. I was fascinated by those, though I had no idea how they would both change the world and touch my life years later.

Education

I got an undergraduate degree at the University of Michigan, and then moved to Stanford because the weather was warmer, and Stanford had a great reputation. I actually didn't know anything about Silicon Valley.

Pang: When would that have been?

Sachs: I moved out here in 1977. The Apple II was announced right around then. I met David Kelley at Stanford, who was the teaching assistant for a smart product design class. He needed some help, because he was going to teach a class on smart product design, and he knew all about mechanical engineering design but not computers, and I knew about computers but not mechanical engineering. So we collaborated, and created this class, which is an ongoing program at Stanford now.

We became fast friends, and when graduation time came a year or two later, we talked about starting a company. He went off and started the company, and I went to Europe for vacation for a few months. I came back, and was one of

the founding principals of a company called Hovey-Kelley at the time (now called IDEO).

I guess I'm telling this chronologically because the mouse design was one of the first things I ever did in my career, and so I didn't really have any history when I worked on it: all the history of everything I've ever done that would qualify me to design a mouse today happened later. I had the benefit of inexperience.

Apple Computer and the Mouse Project

So one of our first clients as a consulting company was Apple Computer. Dean Hovey, one of the principals of the company, met Steve Jobs through someone, and we actually did a mechanical engineering design of the Apple III computer-- a project for which I did some mechanical design of the reset button, my claim to fame in the field, and probably the last mechanical engineering I ever did.

Visiting Xerox PARC

And then there was a new project. Steve was working on a new secret project, pre-Lisa, pre-Macintosh, and around 1979, I, Dean, and a couple others from Hovey-Kelley were asked to go over to Xerox PARC and take a look at a new computer that Xerox had. We weren't told why, it was just something that Steve was doing something with. So we went over to PARC and saw the Xerox Star.

The Xerox Mouse

We got a demonstration of the Star, which had a graphical user interface, a laser printer, and a mouse. The laser printer was so hush-hush that it was kept in another room: they would only show us a printout of it. I always felt that the cooler engineers got to see the laser printer, because that was definitely cool, and I-- being more junior-- was stuck with looking at this... mouse thing.

The story with the mouse thing was, Xerox had done research to find out what the best input system for a computer was-- the best man-machine interface-- and they had looked at joysticks and trackballs and other things. After ten Ph.D.-years of research they had concluded that the mouse was the best input device. However, it couldn't be mass-produced: it was inherently unreliable, it was too expensive, so it was impractical. So it sat-- it languished-- in the lab.

Steve Jobs' Offer

The mouse they had had a mean time between failure of something like one week, at which time it would jam up irreparably, or the little wire fingers

would break. It would jam up on the table-- it had a polished ball bearing that would slide on the table. It had a very flimsy cord whose wires would break. But Steve Jobs said "I want a mouse for \$10. Xerox says it can't be built for less than \$400, but I want a mouse for \$10 that will never fail and that can be mass-produced, because it's going to be the primary interface of the computer of the future."

We of course went back to the office and snickered, and thought, "Maybe he hasn't had enough meat in his diet." [Pang laughs] But if he was willing to pay us \$25 an hour to do this, we would design a solar-powered toaster for him. So we said, "Sure, Steve." Actually, Dean Hovey was the one who came back one day and said, "I've got some good news and some bad news. The good news is, we've got a new project with Apple. The bad news is, I told Steve we'd design him a mouse for ten bucks."

So we set out thinking, we'll design a mass-producible mouse. The end result, a year or more later, was we had a design, filed a patent and were granted a patent, on the electro-mechanical-optical mouse of today, which is still the reference design for PC mice. Somewhere within there is the whole story of how that happened, and what we ended up doing to make the mouse as invisible to people as it is today.

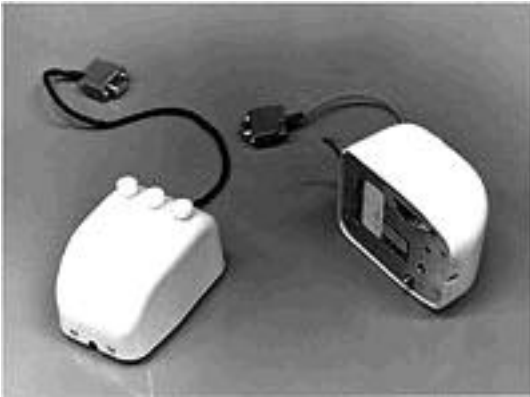
Hovey-Kelley c. 1980

Pang: What other projects was Hovey-Kelley working on at the time?

Sachs: Hovey-Kelley's client base was rather eclectic around 1980. It ranged from our work with Apple on the Apple III, the Lisa keyboard, and a fair amount of the Macintosh; to some laser scanning devices for companies that were making reading machines for the blind that could scan a page of text; to a pressure gauge that could be mounted to a car tire, where you could just look at the valve and see if the tire was over-pressure or under pressure, to touch screen input terminals. Hovey-Kelley's reputation was developing as a company that could take abstract problems and come up with a solution, including the industrial design, mechanical design, software or electronic design, and enough documentation to get you into production. And it solved problems in a very creative way, and that reputation has built over time to where IDEO is today.

From the Lab to the Living Room: Designing the Apple Mouse

Engelbart's Mouse and Jobs' Vision

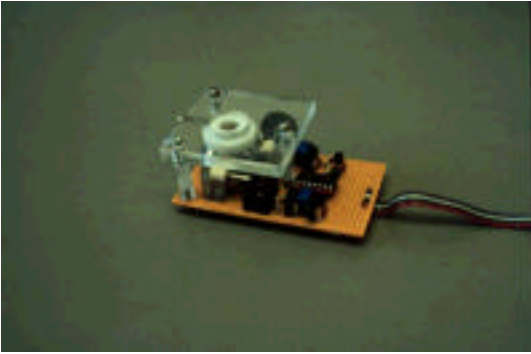


(Engelbart's mouse)

People often ask me, when they see the mouse patent on my wall, whether I invented the mouse. I point out that I did not invent the mouse; I, and the rest of the Hovey-Kelley team, moved the mouse from the lab to the living room. Doug Engelbart invented the mouse. His mouse was crude but effective, and remarkable because he demonstrated it, along with a graphical user interface and all kinds of other things, at Brooks Hall in 1968. A video is available, some of it on the Web, and it's fascinating. Engelbart's mouse consisted of two rotating disks attached to potentiometers, and a big clunky wooden box.

One would never have concluded that that would be the primary interface to millions of computers in the future. I credit Steve Jobs with having the vision that that is the way the masses would use computers, and he was correct. I think he's not been recognized enough for that. I think people tend to spend more time thinking about the young, brash, rude, obnoxious Steve Jobs of the 1980s, not that he truly had a vision for seeing this gem in a lab in Xerox PARC, and saying, "They may not be able to commercialize it, but we can."

So we set about essentially taking a laboratory instrument, the Xerox mouse, and figured out what they were trying to do, and what we needed to do to make it mass-producible. It was the first commercial product I had ever worked on. There was a team at Hovey-Kelley of myself, Dean Hovey, Jim Y., David Kelley, and Rickson Sun. At least three of them are still working together at IDEO, which is what Hovey-Kelley Design later became. We worked as a team to design the new mouse, and I have an archive of the various things we went through to get there-- photographs of the different elements and so on.



(May 1980 prototype)

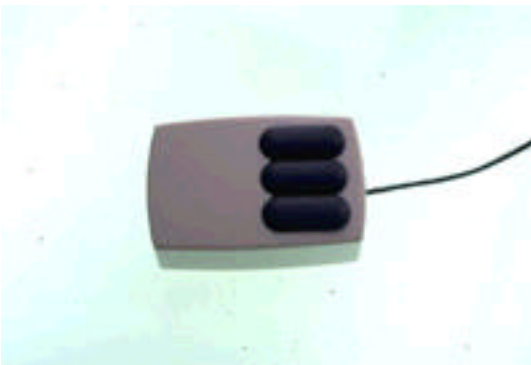
I have here a photograph of the very first prototype, dated May 1980. It was a literal breadboard; It started out when I gave Dean a circuit board and said, "Whatever you make, put it on here, so I can put some electronics around it."

The Team

Pang: How did the labor divide up within this group?

Sachs: I was the electromechanical person and the systems person. Dean was the project lead. Jim was the mechanical engineer. We were the main part of the team. David Kelley had more of the user interface, figuring out what would this look like and feel like. Rickson Sun provided some electrical and optical consulting.

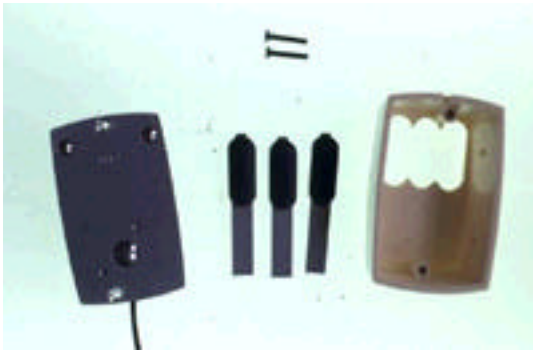
Unconstraining the Mouse



(Xerox mouse)

One of the first things we decided was to attack the failure points. The Xerox laboratory instrument was an over-constrained problem. It was a bunch of ball bearings, held by ball bearings, rolling on a slippery table, so the slightest amount of dirt would jam up the whole thing and it would stop working. It was made of machined aluminum blocks screwed together, and you'd have to completely disassemble it to fix it; and chances were, you'd

introduce more dirt fixing it than you could remove in fixing it.

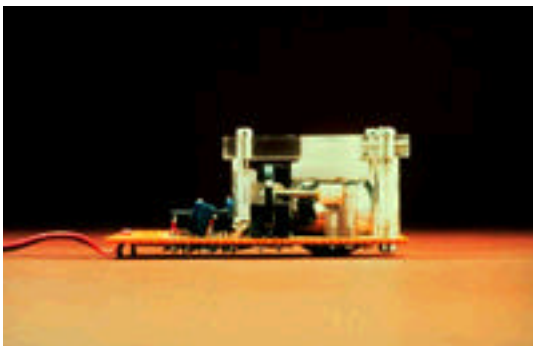


(Xerox mouse)

So we said, "We've got to unconstrain it and have the ball more loosely held. It can't be a tightly constrained ball." So we created a mechanism that had a ball that could roll on a table, and we needed to have an x/y encoding scheme to translate the motion of the mouse into cursor movement-- which is what Xerox did too. But we let the ball float, so that dust wouldn't hurt it, and soft rollers, so dirt could roll through them and not get pinched.

Optical Encoders

The second constraint was they used a mechanical system of a wheel rubbing against metal wiper fingers, which would break and were electrically noisy. At the University of Michigan, I had done a project in an electrical engineering class making an optical encoder, which used the characteristic of quadrature, where you have two optical devices looking at a slotted disk or strip, and could determine motion and position from this setup. I decided we could make a rotary encoder, and have optical components looking at wheels with slots in them, and do it without any mechanical parts rotating up against one another.



(May 1980 prototype)

So the very first prototype had a floating ball, it had optical encoders, we built the circuit, and we were able to roll it around on the table, and the

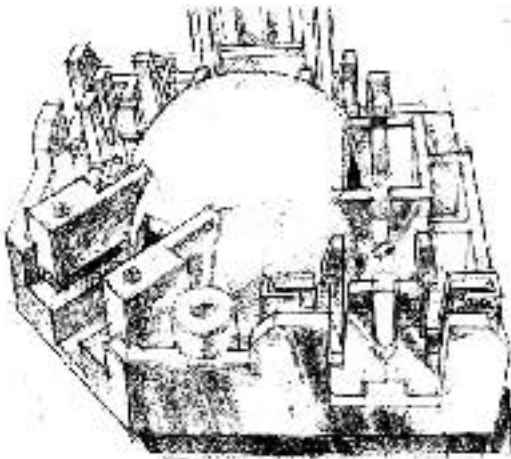
oscilloscope would show signals on the screen. We said, "We're done! It only took two months, and we're done!" Of course, there was a lot more to be done.

Spring-loaded Roller

It turns out one of the next principles-- that resulted in the patent-- was to have a spring-loaded roller holding the ball against the x/y encoders. If you look at any mouse today, you'll see a spring-loaded roller holding the ball against the rollers, and that was something fundamental that we patented that nobody had ever thought of before. I believe it was Rickson Sun who said that component should be spring-loaded, and that it would unconstrain the mechanical system.

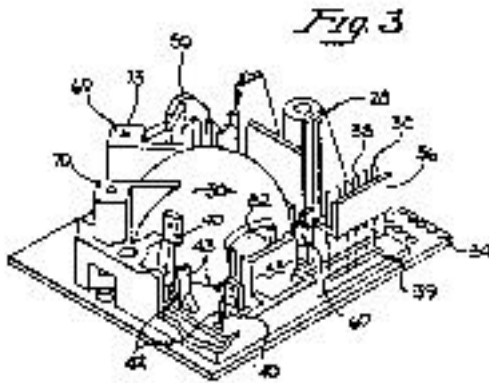
Ribcage

We had solved a number of problems, but we had created something that required such precision it probably couldn't be mass-produced. Our team member Jim Yurchenco said, one way to solve that using known technology was injection molded plastic parts can be made repeatedly, with sub-thousandths of an inch tolerance, with respect to itself. So if we made a single piece of plastic, and located all the components within that piece of plastic, then you wouldn't have any alignment problems with the components over here stuck to the components over there.



(Drawing of ribcage)

And so we designed-- and this is also a fundamental part of the patent-- a single unit which holds the x/y encoders and rollers and bearings-- we eliminated the real ball bearings and used plastic bearings. It also made the mouse easily assembled by untrained people: you didn't even need to screw anything together, everything would snap together.



(Ribcage drawing from patent)

That turned out to be the linchpin. Through optical encoders, through a spring-loaded third roller, and through a unified cage to hold all these parts, we came up with something that made a mouse mass-producible, reliable, and inexpensive, and patented it. And hundreds of millions of them have been made.

Precision in the Mouse

Pang: It sounds as if you were working to a level of precision in the manufacturing that went beyond what computer manufacturers normally had to worry about. Ordinary computer cases didn't have to have this kind of absolute precision and level of accuracy.

Sachs: We were at the intersection of technologies that weren't commonly combined before. Precision electronics had been made, and if you needed it to be extra reliable you could have military spec electronics, were expensive; and you could have inexpensive electronics that didn't have tight tolerances. On the mechanical side, you could have very tight tolerances mechanically in a laboratory instrument, and it would be very expensive; but if it was inexpensive it was sloppy. So we needed to combine all of these, and be inexpensive yet have the performance of high mechanical and electrical tolerance-- which was not anything that you could buy on the market.

The mouse may have been one of the first devices had that had this unusual combination of being a mass-produced, low-cost product, but delivering high electrical and mechanical tolerance. We came up with high electrical and mechanical tolerance by essentially canceling out all the variables. It was all digital, and it was all a single piece. That made it unusual.

Mouse Ergonomics

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So having created this mechanical design that could function, there was still another component of the user interface that I worked on and David Kelley worked on: which was not only what it should look like, but what it should feel like. What would it feel like in your hand, and how would you interact with it? Apple worked a lot on the one, two, or three-button mouse; Xerox had a three-button mouse.

What we immediately noticed-- not knowing what a mouse was supposed to do-- was that it was hard remember which finger was supposed to push which button to do what function. So the Apple mouse went from having three, to two, to one buttons-- which is another significant contribution that Apple made to computing, the one-button mouse.

Designing Without Computers

A sidebar for a second. It's also interesting to note that in 1980, at Hovey-Kelley we didn't have access to a computer to plug a mouse into. So we were a little puzzled as to what this thing really was going to do. People described it: they said, "Oh, it's going to be the primary interface for the computer," which we thought was laughable-- you could balance a checkbook without a mouse, and you could write BASIC programs without a mouse-- that was about all people were buying Apple II's for. That and playing games, and there were game paddles and joysticks, or keyboard input, and nobody thought of what a mouse would be used for in a game. So we had to build an interface card for a mouse for an Apple II, because none existed, and then we had to write software to keep track of the position.

As it turned out, the computer spent most of its time just keeping track of the mouse. Our great accomplishment was to move a dot around on a screen. We wanted to make sure that if you drew circles with the mouse, it wouldn't wander off the screen-- there'd have to be an absolute positioning so you didn't have to constantly pick up the mouse. This is something that Doug Engelbart's mouse had a problem with: it would drift horribly. He pointed out in his demonstration that you could simply pick up the mouse and move it over to re-zero it. We felt that was unacceptable, that it had to be accurate enough that you could move it around for a long, long time without repositioning it.

So it was laughable that we were designing the mouse of today by moving a dot around on a screen. There were no pull-down menus, there were no cursors, there was no highlighting. We only saw a demonstration of a Xerox PARC mouse plugged into a Lisa breadboard computer, attached to a couple pieces of plywood. They had a couple pull-down menus, and they could change fonts, but it wasn't something you could really exercise. That came after the mouse was designed, interestingly enough.

The Feel of the Mouse

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(Prototype mice shapes)

So one of the big debates about the early mouse was, Was this something delicate that you would hold with the tips of your fingers, or was this something that you would grab, like the stick shift of a car or a sanding block? We made probably a hundred different shaped blocks; David Kelley probably still has a box of them in his office. I think he cut the ball off the stick shift of his BMW, which was a dimpled ball, and turned it into a mouse. He made a sanding block into a mouse. We had handles off of bicycles, we had all kinds of odd-shaped things, things that were molded to your hand, things that were perfectly rectangular, to see what the design was.



(Lisa mouse)

The original mouse was designed for the Lisa-- the Lisa came first. The end result was something that we felt you didn't want to grab; you wanted to hold it somewhat delicately, and have your index finger free to click the button. So we ended up having a gentle curved shape, the size of a pack of cigarettes, roughly, and followed the industrial design of the Lisa keyboard-- which was quite a large, substantial keyboard compared to keyboards today. And of course the mouse has evolved over time to the current rounded mouse shapes. And for a time there were mice that were more like sanding blocks; even Logitech built mice that were very very large. But I think in general that, because you want to move your hand to the mouse and back in a gentle motion, not an aggressive, grabbing stick-shift motion, that the smaller designs have become more prevalent.

One-Button Design

As for the one-, two-, or three-button design, we just built all kinds of different prototypes of buttons, and one button seemed easier to use. It might have gone differently if there was software to use that would have shown why you needed a second button. At Apple, the evidence that the mouse was designed first, rather than the user interface, is that only later on did the idea of option-clicking, shift-clicking, command-clicking come about. If we had known that that was required, it might have forced us to make a two-button mouse. I'm happy that that didn't happen, because I think more young children, and more people on planet Earth, have picked up computing because knowing that there's only one button to click. It just makes the learning process that much simpler.

Cleaning the Mouse



Another characteristic which I think is prevalent among mice today is, despite the fact that we'd made a mouse that was compliant with dirt, we were concerned that dirt could still get inside. So one of the first things we did was build a little wiper ring that would wipe the dirt off before it could get inside; but that tended cause too much resistance and was quite noisy. And we ended up coming up with a nifty ring interlock. The user could take it off without any tools, pop the ball out, and expose enough of the parts so they could be cleaned. Any mouse today has essentially the same design. That was a James Yurchenco design: to twist it off, pull the ball out, clean it, and put the ball back in.

Steel v. Rubber Ball

One of the subsequent improvements-- which was learned from actual use; this was the "Once you've designed it, what do people actually do with it?" method-- was that we designed it first with a one-inch polished ball bearing, which was both expensive and too slippery. So we tried sandblasting to roughen up the ball, and that gave it enough friction to use on the table. We weren't using mice pads at the time; that actually came later. But what we did find was that it was a bit noisy. The early mice that were made with steel balls-- and actually shipped with steel balls-- had these tumbled, roughened-up steel balls. If you see an early Lisa, it has a heavy metal ball. The mouse is heavy.

The next step was to rubber-coat the ball, because it was noisy: rolling around a metal ball on a table was noisy. I remember Burrell Smith, who was one of the engineers on the Mac, slamming his fist on the table and saying, "It's too loud! This is the primary interface to the computer, and it's too loud!" Of course, we're still bewildered, thinking, "But nobody's ever shown us what you do with a mouse!" How were we to know that you'd roll it around on the table a lot, and that if it was noisy that might get irritating?

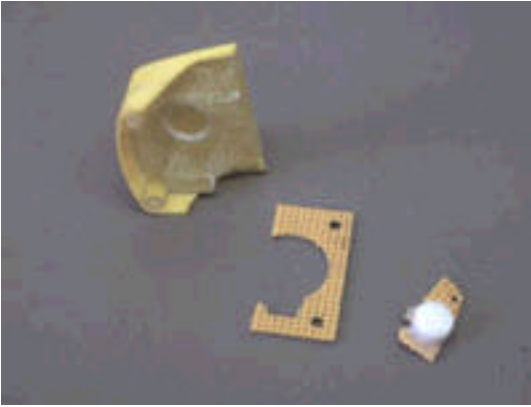
So we rubber-coated the ball, and that quieted it down; but it was still kind of heavy. Later, the proof of mass production showed that you could get all the components working well enough to have simply a rubber ball: it could get enough friction on the table to work, even if you had a little dirt in there. And that's basically what we find in mice today: a rubber ball that has a little mass to it, but no steel ball. And it also still has the optical encoders and wheels and spring-loaded follower.

Stanford Design Program

Pang: Your story about David Kelley sawing off the stick shift of his BMW-- talk about devotion to duty-- and the hundred different models raises this question: How typical was this in product design? Was it normal to experiment with many different kinds of forms and materials?

Making Quick Prototypes

Sachs: All of us came out of the Stanford product design program, and one of the things that was instilled in all of us was to get to a result quickly. So the idea of designing something, and having everything fabricated to your specifications, was simply too long, slow and expensive a way to see if your idea was valid. So it was a characteristic of this group that you make quick prototypes. The way to make quick prototypes is to take apart something else, or find something similar, and glue it together or cut it in half.



(Dean Hovey's prototype)

So that actually was a very common trait for us. Dean actually took a few things apart to make the first mouse: I think his wife found that certain pieces of the kitchen no longer operated because he'd removed some bearings, and he needed Delrin, so he took out a Delrin component from the refrigerator. We all did the same thing: we sacrificed circuitry, we sacrificed anything.

Haltek was one of our favorite places to go. Haltek was a surplus parts store in Silicon Valley: they would buy excess inventory of products that were being trashed, and disassemble them. So you could go in there and buy circuit boards, switches, components. The joke was, your worst nightmare was that one day you'd find pieces of one of the products you'd designed for sale at Haltek. And to this day I think you can still go to Haltek and find inventors who are looking for something that makes a good starting-point, instead of having to start from ground zero.

So this stems from the Stanford philosophy of designing something quickly. And actually, in everything I've ever done in my career, my products have started with a real fast prototype. I'm known for taking some product and running it through a band saw, and cutting off all the pieces I didn't want to come up with something that was a rough model of the final product. It's a proven technique.

Entrepreneurial Attitude

Pang: Was that unusual in design programs? Was it something that set Stanford apart?

Sachs: Certainly in the late 1970s and 1980s, it was somewhat unique to Stanford, especially in that the product design program trained students in a combination of engineering, art, and business. That's why Stanford turned out so many entrepreneurs in Silicon Valley. You have to have a little bit of business sense, and you have to have engineering knowledge, and the aesthetic component was very important-- that's where the art came in. So

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everybody was a combination of those three things. It affected the practicality of a mouse, the engineering of a mouse, and the aesthetic appearance of a mouse-- the user experience.

One of the guys who was at Stanford when we were there, Mark Fuller, was always playing with water. He would buy all kinds of products that involved water, and make some other new product out of them. His most recent design is the fantastic water fountain at the Bellagio Hotel in Las Vegas. It's the most incredible, computer-designed, aesthetic, engineering feat: there's nothing else like it on the planet. And it just characterizes the same themes. So there are Stanford designers all over the planet doing wild and crazy things, whether it's designing electronic books or water fountains. [Pang laughs]

Moving Into Production

Pang: Between the time that Steve Jobs gives you the assignment to produce the mouse for under \$10, and you deliver the model that makes it into the Lisa and is redesigned for the Macintosh, how much involvement did Apple people have in the design process?

Sachs: The Apple involvement was transitional. Hovey-Kelley was actually were responsible for getting the mouse into production in Apple's own factory. They took it over from there, there was minor involvement on Hovey-Kelley's part on a consulting basis after that. It had been documented well enough that Apple could take it over, with one exception.

Crossing Wires

One of the interesting production stories is about my color-blindness. I had built-- myself, by hand-- all of the mice until mass-production. There were a few dozen, and I actually soldered the wires. When we went into production and built the first hundred, none of them worked. They quickly found out that there were wires crossed, and it turns out that because I'm red-green colorblind, I'd misidentified the wires-- but I could consistently misidentify the wires and make them work! I documented it as such. When a non-color blind person tried to build the production mice, they didn't work. I never admitted why: we just said, "It's a documentation error," and I saved the document that showed that somehow the red and green wires ought to be reversed. So that was the transition.

Two Patents

The patent application didn't come until long enough after Hovey-Kelley's involvement that nobody at Hovey-Kelley was given credit for the design: the people at Apple who were processing the paperwork simply put the names of the manufacturing engineers involved. There was no continuity, which was startling, and a patent was actually issued without the names of the people

who actually did the design. When we found this out, we immediately called Apple and said, "We think maybe you forgot the names of the inventors!" And so the patent was actually reissued with the inventors' names on it. The original patent was a combination patent that included both the mechanical mouse, and the notion of pull-down menus, which was Bill Atkinson's work. When they reissued the patent, they elected to split it up into separate pieces, and have the mechanical design of the mouse separate from the pull-down menus.

So an interesting bit of lore is that there are two patents on file, one without the inventors and with pull-down menus, the other with the inventors and without pull-down menus.

Changes After Production

Pang: How difficult was moving the mouse into production?

Sachs: It actually was quite a non-event. Not for the design team to take complete credit, but the whole point was to have the mouse be easily produced. I've never heard any stories other than, how fast could they get the components, and how fast could they assemble them. It has been essentially a trouble-free operation. The design that we created, because it inherently and fundamentally eliminated design tolerance issues, and precision issues, and alignment issues-- there weren't even any adjustments in the product-- allowed Apple simply to build them and they worked. So it might have been a pretty big non-event.

Aesthetics of the Mouse Button

Probably most of the changes had to do with subtle aesthetic things like the feel of the switch. We spent a lot of time figuring out how the switch should feel. Most people never realize that any switch they touch has had a designer agonize over things like, What does it feel like? What does it sound like? How far does it go down? Is it springy or mushy after it goes down? Does it make a sound when it clicks? and How much force is required to press it? Now, all of those things are controllable, and all of those things result in a very different experience, whether it's a key on a keyboard, or the clicker on a ballpoint pen that has a long throw and a "ker-chunk" sound, or the mouse button on a mouse, or a membrane keyboard on a microwave oven. All of them have different characteristics.

And again, we were designing this in advance of knowing really what people were going to do with a mouse. But we felt it was important that a user be able to rest their finger on the button and not activate it, because you didn't want to have to hold your finger up in the air all day. So the original mouse, and I think mice today, had an activation force that won't trigger if you just rest your finger there. But we also didn't want you to have to press too far, and spend a lot of energy, and tensing a lot of

muscles in your hand when you use the mouse. We felt that a good tactile feedback was necessary, so you could feel it click and not only rely on what you saw on the screen. It also had to have enough audible feedback so you could hear it click, but we didn't want it to be annoyingly loud.

So we balanced all those, plus wanting the reliability to be very high, meant using a relatively expensive microswitch in the mouse. With a microswitch, the manufacturer of the switch can tightly control the tolerance, instead of the manufacturer of the mouse having to have a high-tolerance switch design. The one area of very high tolerance and precision in the mouse was in the microswitch, and microswitch manufacturers are set up to do that in mass-production, and to screen them. We chose a switch that we could simply insert into the mouse assembly, and reliably would get this feel that was subjective and appealed to users. And I think that changed over time: I think it was a little stiff at first.

But the issues of mass-production were essentially using a lot of product in the hands of a lot of people to get feedback. Whether it was noise of the mouse, which resulted in a rubber ball; the weight of the steel ball, which resulted in a solid rubber ball, not a rubber-coated steel ball; the activation of the switch; and the shape of the mouse-- what would make your hand cramp and what wouldn't make your hand cramp-- those things then got cycled into mass-production. They were all compatible with one another, except for the connector.

Mouse Cord

Although the mouse cord was always an issue. The mouse cord on the Xerox laboratory instrument was very, very flexible; you almost couldn't sense it was there. But as a result, it was prone to breakage. It also failed what we called the "yo-yo" test, which was, if the mouse was dropped off a table and the cord saves it, did that stretch the cord or break it? But because the cord is coming out the of the mouse and somewhat constraining it, it needed to be very flexible, and not feel like you had a garden hose attached to the mouse.

That required technology that cable manufacturers weren't used to having to care about. They generally didn't have to worry about something being flexible and strong. If it really needed to be flexible, because it was going to be inside a moving component in some mechanism, the mechanism would never yank on the cord; or, it would be very sturdy because you would yank on it, but you didn't need it to be flexible. The intersection of requiring it to be a cord you could yank on and be flexible was something new. It took some time, and I think over time cable manufacturers were able to customize them more, and mouse manufacturers learned what was strong enough and what was flexible enough. Now there are wireless mice, which eliminate the cord completely-- at a price. Back then, it would have been unconscionably expensive to have a cordless mouse, but now it's not so. So [in news

announcer voice] one of the great advancements in mice technology is eliminating the cord. [Pang laughs]

The Zen of the Product

Pang: Who wrote the documentation? Most people are familiar with user documentation, but what is necessary to write down to make it possible to manufacture millions of something you design?

Sachs: Back then, I don't think we knew what documentation was. [Pang laughs] Documentation was the amount of information required so you could get 50 made, and from then on it was somebody else's problem. But then, the mouse was the first real industrial production product I'd ever worked on.

Communicating Intangibles

In mechanical engineering, the documentation really is an adequate set of documented drawings, and a parts list. Beyond that, there was so much intangible intellectual property about how something works that it was really transferred verbally, or through team meetings about what was important. So a design team would sit down with a manufacturer and transfer their knowledge in an interpersonal communication rather than a technical specification, because so much could be lost if you simply said, for example, "This needs to be lubricated with lubricant X," instead of having them understand that that lubricant X is so critical that if you contaminate any other part of the system with it it'll fail after a year. We wanted to transfer more than just the basic information. So it was really a human-to-human team knowledge transfer. From there, Apple took care of documenting it for their own manufacturing purposes and their own archives.

But often what is lost in that kind of historical documentation of a product is the Zen of the product, because it's something you can't write down. You could write down that a switch should have a certain activating force, and a certain sound-- though a sound is hard to document without sampling it. Certainly it's almost impossible to document the feel of something. And so you describe it. And to this day, in 1999 and 2000, that's true. At SoftBook, we have a product that has a switch-- the page switch of an electronic book-- and when it comes to final approval, they actually give it to me, and I feel it and say if it has the right feeling or not. Because somehow or another, it's my brain, and my tactile senses that's calibrated to know what feels right. And then when we make enough of them, other people can feel it, and they get accustomed to it, and they too can pass on the right feel. But ten years from now, if there's a lack of continuity, the feel of something is not something we have the ability to document. You would have to go back and refer to an actual sample to refer to-- and possible other samples, so you can see that this one is too stiff, and this one is too soft, and this one is too loose-- so people can get an understanding of why this one is the way it is.

That's the Zen of the product, which fortunately we have the ability of transferring personally from one person to another. For a practical point, the way we do this in mass-production is, a designer goes to the factory, and is there on the assembly line seeing to it that the Zen of the product-- in addition to the technical specs-- are there. Because there are some things you simply can't document, or things where language fails us. The only solution we have found to almost guarantee satisfaction is to have a human go to the location, actually use all of their senses to determine-- along with the written documentation-- that it is what it's supposed to be.

The Zen of Mouse-Computer Interaction

One example of the Zen of mousing has to do with the tightness of the interaction between the mouse's actions and the computer's response. There was always a big difference in this between the Macintosh and the PC, for those of us accustomed to the Mac. The Macintosh was designed with the mouse as part of the system, and there was a very, very tight interaction: both a precision of motion-- of moving the pointer around on the screen-- and a feeling that you had total control of where that pointer was, and its speed and position. With the PC, because the mouse was an add-on, there was almost a rubber band-like connection between your hand and the mouse: either the mouse would lag behind, or it would stutter, or you would have trouble making a precision alignment. That interaction has always, maybe until quite recently, a distinct advantage of the Mac over the PC. The mouse was such an integral part of the design from the beginning that the precise control became apparent when you moved away to a PC.

I have a theory that one never notices how fast a computer is, you only notice how slow a computer is. A similar thing holds true for the mouse: you don't notice how tight the interaction is until you go to another machine, where there's a very loose interaction, which becomes quite annoying. So as computer technology has changed, the interface between the mouse and the computer has improved consistently to provide that superb connectivity between the hand-eye coordination, and what goes on on the screen. You see this with the USB mice of today, where the mouse has to be given a very high priority: when you move it, the cursor or arrow has got to move regardless of what else the computer is doing because it's a very disturbing thing to have a delay. It's like an echo on a telephone-- you just can't ignore it.

As a result of that, we always felt that people who used early PCs didn't know what they were missing. I found the early PCs unusable, either because the mouse itself was designed as an awkward block with three buttons, or because the interaction with the machine was lame. And yet hundreds of thousands, if not millions of people, were told that this is the way a computer is supposed to work. For a while I thought that it might kill the mouse, because people wouldn't like it. But people were resilient and patient, and computers improved over time, so that now, I believe, all

computers have a fine interaction between-- in this very subtle manner--
between what your eye and hand do, and what system actually does.

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